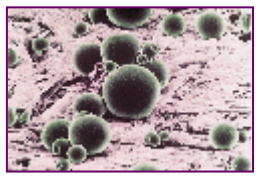
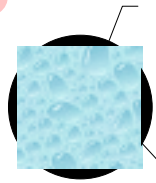
Use of Encapsulation Technology for NLW

DropBooks



Secondary delivery



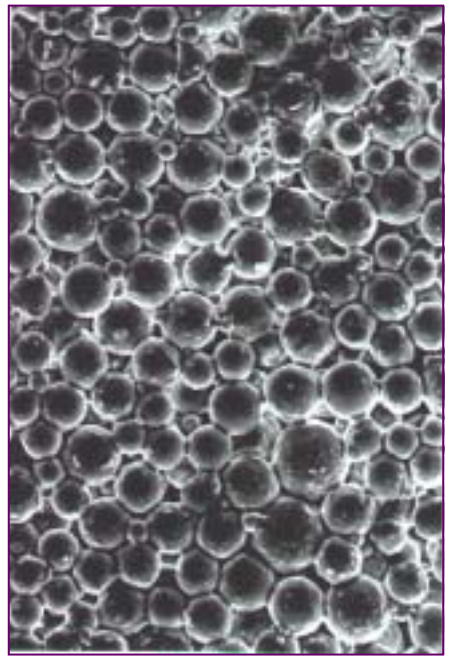
Wall material with properties specific to application

Active material

Primary delivery

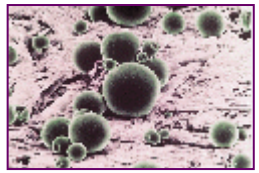
Why encapsulate NLW?

- To achieve controlled/remote-release.
- Make active materials easier/safer to handle.
- Compartimentalize multiple component systems.
- Protect sensitive materials from their environment.
- To turn liquids into powders/solids.



You are (very) familiar with microcapsules

Razor Blades
Thread Lock Fasteners
Fertilizers
Pesticides
Toothpaste
Shampoo
Bath Salts
Sachets
Scratch-N-Sniffs
Scented Papers
Extended Relief Pharmaceuticals
Carbonless Paper
Detergents & Bleaches
Antiperspirants
Air Fresheners
Vaccum Cleaner Bags
Fire Retardants
Waste Disposal Systems
Kitty Litter
Facial Tissues



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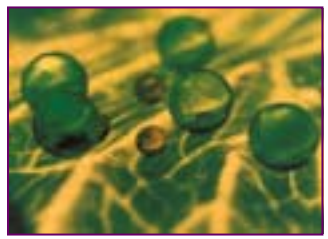
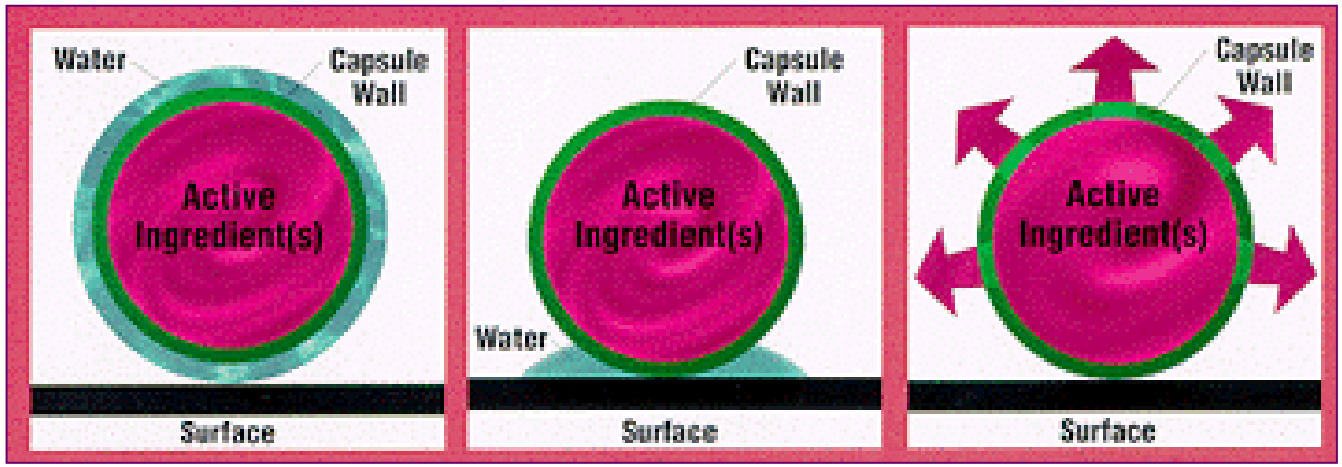
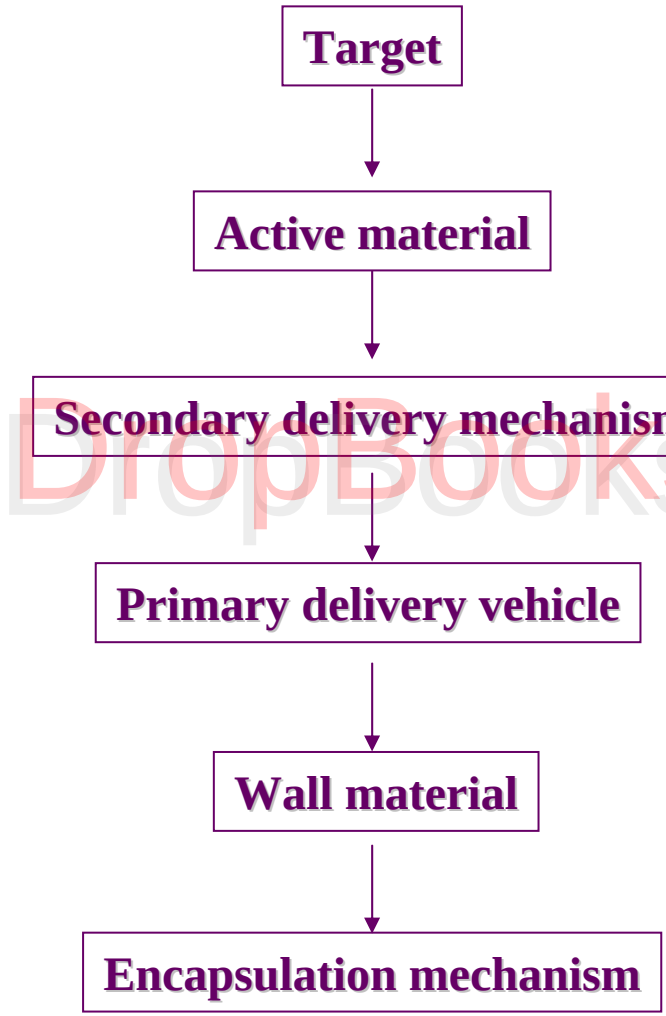


Example of release



Selection process



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Target / Potential active materials

Anti-Material

- Combustion modifier
- High viscosity polymers

Anti-Personnel

Color dyes

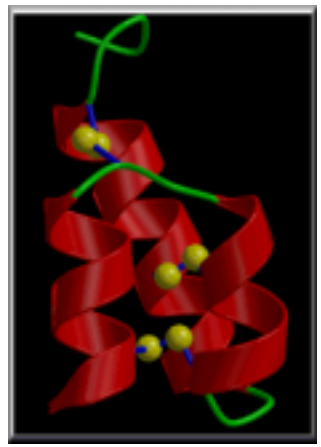
Mark the opponent for easy identification (chase situation)

Pheromones

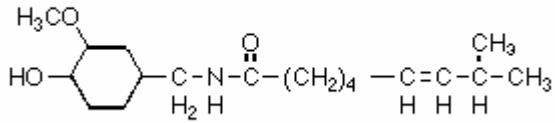
Discomfort inducers

Loss of vision
Coughing
Disorientation
Vomit

Anesthetic
Paralytic



Capsaicin



Secondary delivery (release mechanism)

- **Mechanical rupture (weight of a human)**
- **Thermal release (activation temperature)**
- **Shell dissolution (presence of water)**
- **Photolytic release (exposition to (sun)light)**

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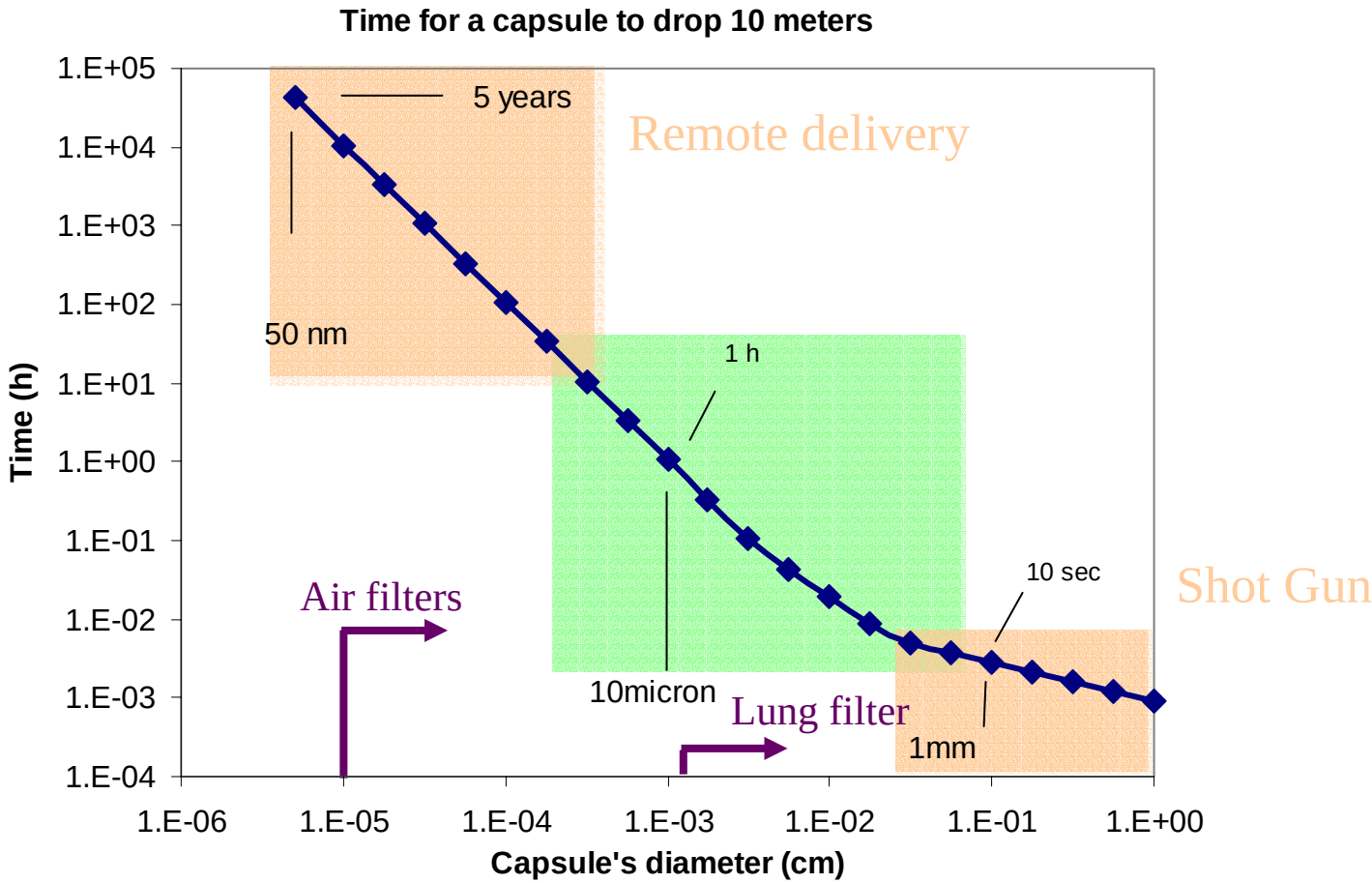
- *Osmotic and pH-dependent release*
- *Enzymatic release*
- *Electric current*

Capsule sedimentation.... Fog or sand ?



Primary Delivery

Shotgun
Hand grenade / grenade launcher
with very small explosive load
Objective Individual Combat Weapon (OICW)
Planned to have a 20mm high-explosive (HE) air-bursting ammunition, with range and fuse delay controls
Mortar / gun with fragmentation shell.
Unmanned Aerial Vehicle (UAV)
Missiles
with modified release - drop and exit strategy

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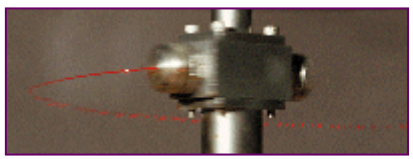
Capsule wall material

- Natural Polymers
  - Proteins (gelatine, albumin, casein…)
  - Carbohydrates (gum arabic, agar, starches, xanthan…)
- Semi-synthetic polymers
  - Cellulose esters and ethers
  - Fatty acid derivatives
  - Fatty alcohol derivatives
- Synthetic polymers
  - Vinyl (co)polymers (polyacrylamide, polymethacrylate…)
  - Polyamides and polyesters
  - Poly condensation type polymers (polyurethanes, epoxy...)
  - Polyolefines (paraffin, hydrocarbon wax…)

Encapsulation methods



Physical methods	Size, micrometers
Spray drying	5-500
Rotating disk	5-1,500
Stationary extrusion nozzle	500-4,000
Centrifugal extrusion nozzle	250-2,500
Submerged extrusion nozzle	500-6,000
Air suspension	> 75
Pan coating	> 1,000
Chemical methods	**Size, micrometers**
Simple and complex concentration	2-1,200
Interfacial polymerization	2-2,000
Phase separation	0.5-1,000
Solvent evaporation	0.5-1,000
In situ polymerization	0.5-1,000
Super swelling polymerization	0.5-500
Mini emulsion polymerization	0.1-0.4

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Selection chart - anti material

Target —— Ship at sea / cooling system

Active material ——
- Poly(N-isopropyl acrylamide) (NIPAM) becomes very water soluble at T>62°C
- Bicomponent polyisocyanate / polyol creates a polyurethane foam

Secondary delivery —— Temperature release, low density (0.8g/cm3), 1micron diameter, biodegradble (1 month)

Primary delivery —— Air/sea-sea missile, UAV

Wall material —— Low molecular weight polyolefine (wax)

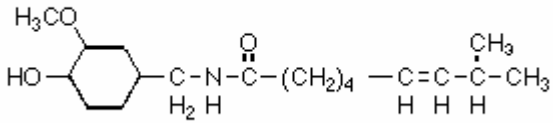
Encapsulation mechanism —— Meltable dispersion process

Selection chart - anti personnel

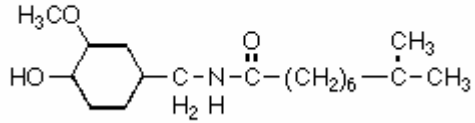
Target — hostile crowd / vision-lungs

Active material —

Capsaicin



Dihydrocapsaicin



Capsaicinoids (chili peper)

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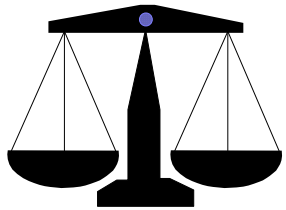
Secondary delivery — Pressure / mechanical release, 1mm diameter

Primary delivery — Shotgun, OICW, hand grenade, UAV

Wall material — Poly methyl methacrylate (PMMA)

Encapsulation mechanism — In-situ polymerization / interfacial polymerization

Pros



Cons

- Projectable at long ranges
- High flexibility
- Multi chemical mix
- Prevent redirection
- No restriction of offensive / defensive capabilities
- Use existing delivery vehicles
- Light weight
- Safe to handle
- Biodegradable
- Local area exposure
- Potential for strategic NLW

- Reaction time
- Mutiple countermeasures can be developped
- Vulnerable human organes exposure (lungs / eyes)
- Individual exposure control